BIOLOGICAL CLOCKS

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PREFACE

From childhood I have been interested in the strange behaviour of plants and animals. Touching the *Chui Mui* (Touch-me-not) plant used to be such an attraction that whenever I got a chance I spent quite some time to watch the behaviour of the leaves. Just touch the leaves and the leaves will fold as if they are dead. After some time they would again open up and stay erect. What a fascinating experience it used to be!

In our garden we had sunflower plants also. Large flowers with yellow petals and chocolate centre! What a beautiful sight! And sunflowers surprised me with their unusual behaviour. They changed their position with the changing direction of the sun. As the sun goes from east to west, the flowers also shift their face position as if following the sun. The movement of sunflowers was another discovery.

In the summer, the cluster of tiny white flowers of Raat Ki Rani (The Queen of the Night) would open after dusk and spread their fragrance. I recall once taking a stroll with my mother in the garden. It was a moonlit night in summer and the fragrance of white flowers attracted me. As soon as I reached my hand to pick the flower, mother held my hand, "Do not disturb the plant. It is sleeping," she said. Since then I never touch the plants at night. Years have passed since this incident happened but the impression has remained. That was my first encounter with the rhythm of the plants.

In the courtyard of my house, a pair of wagtails came every winter. I fed them with grain and also placed a bowl of water for them. They disappeared around March and returned again at the end of October

With the onset of summer, squirrrels and lizards suddenly start to appear in the house and disappear when the winter comes. As a child, I used to watch in amazement how the lizards ate up the insects. During the rainy season, glow worms twinkle near the wet bushes in the night. After the rainy season, colourful butterflies appear.

After dark, moles and mice are regular visitors in the kitchen and as children we set the traps for them in the evening. Every morning, we found one or two were trapped and despite this their behaviour pattern did not change. These observations made me curious to know more about strange behaviour of plants and animals.

Years passed, One day, a news item in 1967 caught my attention. A feature in the continent of Antractica, 83^0 57south latitude, 170^0 06 east longitude, had been named Sirohi Point after an Indian plant physiologist, Gir Raj Singh Sirohi. I located him at the Indian Agricultural Research Institute in New Delhi and learnt about his work on 'biological clock' and also how he had gone to the South Pole for his scientific experiments. His story fascinated me and I wrote a book, *100 Days in Antarctica* in 1979.

My curiosity about the 'biological clock' got deeper and I wanted to know more about it. I observed even the daily behaviour of human beings. How an old lady in the neighbouring house, got up exactly at four o'clock in the morning without the help of any watch or alarm. Then I learnt how important this 'biological clock' is for all living beings.

'Bio' is a Greek word which means 'life' and 'clock' is a time measuring device. 'Biological Clock' is a life's clock. Often there are more than 100 clocks which regulate everything inside a living being.

The working of the 'biological clock' is more precise in birds, animals and plants. Since we human beings rely more on artificial devices and keep fighting with our natural 'biological rhythms', the clocks in our system

have become less sensitive. The animals, plants and birds still have their natural device, the 'biological clock', intact which guides them in their behaviour at different times precisely and appropriately, as this is important for their survival.

With the awareness that time is valuable, over the ages man has developed his own devices for measuring time. He has used the sun dial, water clock, candle clock, mechanical and electronic clocks. Today, if the clocks of the world stop working, no one would be able to do any work on time. The trains, the buses, the aeroplanes, even radio and television, the entire life will be dislocated. Thus, modern life has come to revolve around the mechanical or electronic clock and all our activities depend on it. The life pattern of a modern man interferes with the natural rhythms commanded by biological clocks.

I am thankful to Dr. Sirohi who has generously spared his time for consultation. I also acknowledge my sincere thanks to Dr. M.K. Chandrasekharan of Madurai University, who, besides giving me a lot of information, has let me use some of his observations in this book.

I am indebted to late K. Shankar Pillai, the famous political cartoonist, who always encouraged me to write books for childern.

I dedicate this book to my parents and specially to my mother who had once asked me not to disturb the plants and had aroused my curiosity towards the behaviour of all living beings.

Manorama Jafa

New Delhi, October, 2000

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1

BIOLOGICAL CLOCK:

An Infant Scientific Idea

It was a sunny afternoon, many many years, ago when Alexander the Great, camped near a jungle in the north of India. After the troops had settled down, Androsthenes, a commander in Alexander's army, dressed himself in ordinary clothes, asked his chief's permission to have some fresh air in the wilderness.. The chief was taken by surprise.

"But you must be tired, Androsthenes."

"Oh, no sir..." and before Androsthenes could finish, the chief added, "I know, I know. You may be wanting to look at some plants."

Androsthenes saluted the chief and walked away.

Androsthense loved to look at different kinds of plants and study their foliage, their buds and flowers. He now walked straight to the woods. He knew many of the plants but some of these he had never seen before. He was fascinated by the shapes of their leaves and their lush green colour. He observed that as the darkness fell, the leaves of the tamarind tree did not remain erect but were drooping. As he walked back to his tent, he was still thinking about the drooping leaves. For a moment he thought he

was mistaken and decided to go back and look at the trees again. Of course, the leaves were drooping.

The following morning he again rushed out to look at the plants and to his surprise the tamarind leaves were open and erect. And in the evening the leaves were drooping again. He observed this pattern of leaf movement for several days and kept a note in a handy diary. This was perhaps the first ever record of the timing rhythm in plants.

For long, people have observed the behaviour pattern of plants, worms and animals and discovered many interesting examples of a timing mechanism or rhythm in nature. With the first rain in summer, frogs and toads appear all over the place. In winter they disappear and go in hibernation, and are not seen until the rains come again. It has also been observed that frogs appear on about the same day, every year, at the same place. They are also known to hop to the same pond, year after year, generation after generation and to breed almost at the same time. Not only that, at the set time of the year they come out and follow the traditional routes. Once, when a main road was built across one of these migration routes, hundreds of dead frogs were seen killed by the night traffic.

Similar rhythms are also common in the behaviour of plants, insects, birds and animals. Scientists have been astonished by the uncanny sense of time exhibited by birds, bees, worms and plants in their day-to-

day behaviour. An internal timing mechanism guides birds to know exactly when to migrate to the warmer regions to avoid extreme cold of the north. Owls, rats and cockroaches sleep during the day and are active at night, whereas other creatures commonly restrict their activity to day-light hours. Bats fly out evening after evening with great precision. Crows, mynahs, squirrels are up at about 6 a.m. and retire at about 6 p.m. even when they are kept in windowless rooms where they cannot see the sunrise or sunset.

In the plant world too similar examples are found. The bean plants fold their leaves during the night and open in the day. Flowers open and close at certain times of the day with surprising accuracy. Morning glory, a common garden creeper, and portulacca flowers bloom in the morning and as the day grows, they lose their fresh looks and by evening they are closed. Next morning, the plant is again full of blooming flowers.

Observing the time of the opening and closing of flowers, Linnaeus, a Swedish naturalist, got a fascinating idea. He constructed a flower clock and by looking at the bloom that was out at a particular time, he knew the time of the day.

The biological functions of the human body too go on uninterrupted like a clock. These rhythms function even when man sleeps or keeps

awake, often without his knowledge. The different functions of the human body follow a rhythm or a set pattern over a twenty-four hour period. Thus the temperature of the body, eating and sleeping patterns, breathing, heart beat and chemical activities of the kidneys, liver, digestive system and nervous system—all seem to follow a regular rhythm. Persons travelling by aeroplane over long distance experience disturbance in their sleeping and eating patterns. It takes a few days before the body readjusts itself to the change of the timings. This happens due to disturbance of the normal daily rhythms of the body functions which dislocate not only the sleep but also functions of the body.

In nature too, things go on according to certain set patterns. The earth rotates on its axis once in twenty-four hours, giving us day and night. The number of hours of daylight every day varies with the seasons and repeats the same pattern year after year. The earth's revolution around the sun gives rise to our seasons. The movement of the moon around the earth and the earth's revolution around the sun together give us the lunar month and the cycle of tides.

In several parts of the world, marked seasonal changes occur in the temperature and humidity. Thus the climatic conditions at certain seasons may even threaten the life of animals and plants. In severe cold weather at higher altitudes, life becomes extremely difficult. Similarly, some areas become very dry. Many plants and animals in such areas use the changes in day length as the indicator of the season and their biological clocks influence a change in their behaviour patterns. In plants, the flowering, the beginning and end of the period of dormancy in buds, seed germination and many other processes are thus regulated by an in-built timing mechanism. Thus, every year, as September arrives, nasturtium seeds left over in the flower beds from the previous year begin to germinate and by January pretty yellow and orange flowers bloom. In animals, the periods of

hibernation, migratory restlessness, changes in colour and thickness of pelt are similarly regulated. Some of these plants and animal species are activé during the long summer days with dormancy coming over when autumn comes. Other organisms are acive during shorter days of autumn or winter and remain in an inactive or dormant state during summer, mainly when the season is particularly hot or dry. But the most surprising fact is that when the correct duration of the day-time (or the night-time) arrives, the organism's behaviour pattern, like the flowering in plants, changes abruptly from one seasonal rhythm to another.

Some long-lived plants and animals possess a different rhythm, regulating something like an annual cycle. These annual rhythm of seasons control breeding, wool growth and hibernation among animals. Domestic sheep have an annual cycle of wool production, which increases during the summer months. Sheep kept under experimental conditions of continuous light maintain such cycles. Rodents exhibit cycles of hibernation and activity, often disappearing and again appearing at precise times of the year. In ground squirrels, lizards and snakes there is a clear cycle of hibernation, change in body weight and temperature. Their body weight is the maximum when they go into hibernation and the minimum when they 'wake up'. During a visit to the Kanpur zoo, I have seen preparation for the "waking up" of the hibernating snakes. A few mice were introduced in the cage for the snakes to have their fill on waking up.

The bird and animal travellers of our world cover long distances year after year at almost the same time and the same way, which is of course very fantastic. Birds are the greatest of all travellers, but even the spider, crab, tortoise, fish, all leave home when the moment is right. Imagine the tiny, exotic humming birds and the lovely, fragile butterflies setting out on a journey hundreds of miles long.

It is amazing that all living things have their own 'built in' clocks, which continue to work by themselves with precision even when they are kept away from light in constant darkness and at constant temperature. It is not only the everyday life of the plants, birds and animals that is guided by a natural time sense but also their seasonal behaviour. Many research workers all over the world have studied these behaviour patterns and have found that plants and animals have their own biological clocks. This biological clock enables them to measure time and determines the rhythm pattern in their behaviour.

Until recently these observations were regarded as only interesting events in the life of plants and animals.

Then Gustav Kramer, a German scientist, who had been studying birds' ability to navigate by the sun, found that a bird might be able to use the sun as a compass and even have a time sense, that is, a biological clock, which enables it to adjust its course to compensate for the sun's movement across the sky. Ever since, the term 'biological clock' has come into general use.

The 'biological clock' concept led to many new scientific observations. Even the old observations now acquired a new meaning and are now better understood. These observations clearly showed that repetitive activities of plants and animals have rhythms—some occur once in twenty-four hours, others occur every hour, or even every second. In some living beings these rhythms occur every week or every month, in some others it may occur only every seven years, or even every seventeen years.

The idea that all living beings have an in-built biological clock has contributed greatly to the understanding of the life sciences. Before we learn more about the biological clock, let us look at some truly fascinating examples of the timing mechanism in nature.

2

TIMING MECHANISM:

Some Fascinating Examples In Nature

Migratory Birds

Bharatpur in Rajasthan has the largest bird sanctuary in Asia. It is full of marshes and trees and it has become a paradise for migratory birds. Once, early in November, I visited the Bharatpur bird sanctuary and was pleasantly surprised that several migratory birds from cold regions had already arrived. Here, I saw the Siberian white goose, Siberian white stork, and the Arctic tern. These birds begin their journey in early September and take almost two months to finish up long journey. They prefer to settle down on trees which are surrounded by water. It is fascinating to watch them in the sanctuary. The whole place looks like a den of birds and human beings look like intruders. In Chilka Lake, in Orissa, 97 varieties of migratory birds come every year. By end of November Chilka has 20 lakh feathered tourists and a total of 156 varieties. In early March when the weather starts warming up, these birds are ready for their homeward journey and following their leaders, they fly towards north. Bird watchers have found that the

Salim Ali

migratory birds follow the same path and almost the same timings year after year. Salim Ali, the well known Indian orinthologist, has recorded that a ringed grey wagtail was found to return, presumably from its Himalayan breeding grounds at least 2000 km. away, to a particular lawn in Greater Bombay, no bigger than a badminton court, on almost the exact date in September one year were retaken in nets at about the same place in the same month, almost to the date, in the following year; in one case even in each of the three successive years.

The most important factor responsible for this set and strange behaviour must be 'self-preservation'. However, even in cold countries not all birds move to warmer climates. Penguins stay on the continent of Antarctica. Young Siberian jays adapt themselves to the cold, huddle together for warmth in an early frost in the north of Europe and Arctic region. But these non-migrant birds are thickly feathered and also no bigger than a badminton court, on almost the exact date in September for five years in running. Incoming Orphean warblers ringed in Saurashtra in September one by fluffing out their plumage and trapping their own body heat, they can further insulate themselves. Thus they do not need to migrate to escape cold. At the same time, if food becomes scarce, they also fly as far as central Europe to seek it.

Monarch Butterflies of North America

Monarch Butterfly

Monarch butterflies are widely distributed in the United States and Canada. The Monarch is a beautiful butterfly of chestnut colour. It has black veining on its wings and is three inches across the spread wings, much bigger than the common Indian yellow butterfly. These Monarchs migrate in millions every year and the sight of these exotic migrating butterflies has aroused curiosity and has been widely studied. Early in September, the Monarchs begin to fly south. This movement starts in the most northerly parts of their range, when in twos and threes they set out to fly south. As they do so, small groups join up to form larger and larger groups until there are steady streams of millions, stretching for long distances. One stream goes down to pacific coast, the other stream down the eastern U.S.A. even as far as Mexico. The streams of Monarchs cross eastern North America in the direction of Florida and Texas and along the west coast to California. Arriving at the destinations they pass the winter in a state of semi-hibernation on the trees, hanging by the thousand on each tree. Although the same trees are used year after year, it is not the same butterflies that use them but their children and grand children.

After a long sleep of a few months, in the month of March the Monarchs become active again and fly back northwards arriving in south Canada

about the beginning of June. The return journey from Canada to Florida or South California is well over 3,200 km.

There is a small jungle near San Francisco. Here Monarchs have assembled to hibernate for over sixty years. Their dense masses present a fascinating sight and are a great tourist attraction. Chestnut clouds of butterflies cover the sky and present a picturesque view. The trees on which they settle down to hibernate are known as butterfly trees. The time of their arrival and their settling down on trees present rare sights. The local authorities take special precaution to preserve this ecology. Anyone throwing a stone at the 'butterfly trees' disturbing them and harming them in any way can be fined up to 500 dollars.

White Butterflies of East Africa

Dr. Williams, one of the great authorities on migratory insects, has given an interesting account of white butterflies on migration in East Africa. His cottage was situated at the top of a raised ground, was in the path of the migrating butterflies. During the course of their flight when they passed by this house, the butterflies began to beat themselves against the wall. Instead of going round the house, however, they retreated, then flew higher, going up the wall and over the roof to maintain their original direction.

Grunions of Southern California

Grunion is a slender silver fish. It rises on the crest of the waves as the high tide recedes in the sea off Southern California in the U.S.A. The fish is washed on to the moist sand and spawns, and then flips back towards the water.

The timing sense of the Grunion is so precise that it comes about fifteen minutes after the high tide, when the water is just a few inches lower. At that moment, the fish lays eggs in the sand. These remain buried in

the sand and mature and are ready to hatch in fifteen days when the next high tide arrives. As the waves churns the sand, the baby fish are freed from the egg pods and are ready for their journey into the sea.

The Grunion hunters make it an occasion and hundreds of them come with their buckets to catch the fish. It is quite easy to know when the Grunions will come, but it is amazing how Grunions know exactly the time most suitable for the survival of their young.

Palolo Worms of Fiji

A similar spectacle takes place over the coral reefs near Fiji and Samoa. At about dawn on the first day of the last quarter of the moon in November, the Palolo worms swim to the ocean surface in large numbers. Just before dawn people of Fiji and Samoa bring their boats and canoes directly over the reefs where the worms will rise and scoop them up as much as they wish.

Three-hour Bird of Panama

In Panama, Pileated Tinamou is a fascinating bird species, resembling a tiny ostrich. The bird sings every three hours, day or night. It is so punctual that in Panama it is called a three-hour bird.

Pair of Kites or Temple Birds of Tirukkalukundram

Tirukkalukundram is a hill shrine on the [illegible] road between Chingleput and Mahabalipuram in Tamil Nadu in India. Exactly at twenty-four hour interval two kites arrive at a fixed time everyday, an hour before noon, to be fed by the priests. This unusual behaviour of the two birds is explained by a fascinating legend that the birds are in fact two saints, who take a break at this spot on the flight from Varanasi to Rameshwaram. Scientifically this visit could be explained that these birds have time memory which is guided by their 'biological clock' and they keep visiting the temple at the

fixed hour. However, twenty-four hourly visit by only two birds for generations is still an unexplainable miracle.

Himalayan Birds and the Weather

Mountaineers in the Himalayas generally have to depend on their sherpas' experience to know about favourable weather conditions for climbing. Few year ago Yuichi Matsuda, a Japanese mountaineer, discovered that the movements of migratory birds have something to do with the weather. He observed that Siberian cranes migrate for about ten days after the monsoons or in the beginning of October and also that during their migration, weather thoughout the Himalayas remained clear and best suited for climbing.

Similar interesting observations have been made by man for a long time. But these were long regarded as only fascinating events of local importance, not as a part of the grand design in nature. Only in recent years scientists began to ask themselves what brings it about, and how. In the 1960s, it came to be widely accepted that an internal clock determines the behaviour pattern in living organisms. In the pages that follow we shall see the nature of the clock and how it effects the behaviour patterns of living beings.

Touch me not(Chui Mui) plant

3

THE SCIENTIFIC PURSUIT :

The Idea of The Biological Clock

The daily leaf movements in plants were studied by Androsthenes over 2000 years ago and are among the earliest observations of the twenty-four hour rhythm. In the eighteenth century, French astronomer, Dr. Mairan, also observed these movements and moved one step further. He transferred his experimental plants to a dark cellar to see how far the darkness affects the behaviour of plants. To his great astonishment he found that the leaf movements continued in the total darkness the same way as in the daylight. This experiment led him to conclude that the leaf movement was guided by an internal clock-like mechanism.

In the fascinating world of nature, the 'biological clock' enables plants and animals to divide their time and adapt their behaviour pattern to suit their best advantage. Thus, quite a few animals move about in search of food only when it is totally dark, while others use the same food resource during the day. This behaviour pattern reduces direct competition between them.

The 'biological clock' also enables the animal or plant to 'prepare'

Honey Bee

and 'anticipate' a situation. The external stimuli like the daylight and temperature also affect their behaviour in many ways but the 'biological clock' enables them to remain wholly self-reliant. Thus, the mouse does not have to depend for being woken up abruptly by the approaching darkness. The 'biological clock' slowly prepares him for the waking up process. The same way, the honey bee is also guided by its 'clock' to know or remember when exactly the flowers will have nectar for it. Such rhythms are like 'ringing a bell' and telling the insects, plants and animals that it was time for them to follow a particular behaviour. This is like a clock alarm, signalling the occurrence of an event at fixed intervals of time.

Over the years, most of the scientists favour the view that the timing mechanism in plants is located within the living organism. Also for a long time many scientists have regarded the timing patterns in plants and animals as wholly guided by the in-built 'biological clock' though they recognise that some external factors, such as daylight, temperature, seasons also influence the behaviour patterns. However, other scientists consider the timing patterns to be mainly influenced by external factors. The main curiosity now revolves on how far the environment plays a part in the behaviour patterns.

The yearly migration of birds from the cold regions of north to the

warmer regions of south in winter provides a good example of the timing sense in the birds. What prompts birds to start their migration at approximately the same time every year? The scientists have been baffled to find that the timing sense of the birds is so precise. Their observations led them to believe that one of the factors which seems to start these changes in their behaviour is light. When the light decreases in autumn, the birds prepare for

their southward journey and with the increase of light in spring they again start their homeward journey. Still it is a mystery that when the right day comes, the birds not thinking how and why, leave for their distant goal. How they find out the exact time, no one understood for a long time.

The scientists knew that there was some special sense of timing which guided them to travel in a particular direction. Some scientists thought that it could be guided by some external factors. This group of scientists stated that birds in the cold northern regions start planning their journey in early autumn when the light of the sun starts thinning. They start flocking together and they fly southwards. The annual behaviour of birds connected with the sun's diminishing light was an interesting and strong point. But some scientists argued that though the sunlight and temperature certainly help birds to move southwards, this alone was not enough and did not fully explain the birds' behaviour concerning their sense of direction.

Ring is being examined to record facts about the bird's migration behaviour

It is now generally accepted that sense of timing and sense of direction of birds' navigation are closely associated phenomena. A number of factors besides light may play part in the birds' timely flight in a definite direction.

The curiosity to know about the mysterious journey of the birds prompted the early bird watchers to follow these birds and find out when and where exactly they moved in winter and how they appeared again. They followed the birds with the aid of binoculars, telescope, radar, aircraft and other tracking devices. Many of them trapped the birds in nets and dyed them before letting them free again.

Of all the ways men have devised for following the birds, the most effective is the process of ringing, which picks out a single bird at two specific moments. First, when the ring is snapped around the bird's shank and second again when it is once more recovered from the bird found alive or dead. These light aluminium or coloured plastic rings carry the name of the place where they are ringed and the date when they are ringed. This method has proved very successful and scientists have been able to record many startling facts about the behaviour of birds, like the time of their departure and return, direction of flight and the distances they cover during these migrations.

Once I stood in an open corner of the Delhi zoo in the month of

November when a white bird with a long beak settled down close to me. A bird watcher quickly spotted it and I heard him saying, "A bird from Siberia". I rushed to the gentleman and asked. "But how do you know?" He explained that a few days ago a similar bird had been captured in Delhi. It had a ring with Russian lettering on its shank. The bird had probably migrated from Siberia and must have been one of the many thousands that flock to northern India during winter months which both the Soviet scientists and the Bombay Natural History Society keep track of.

It is really strange that the birds can follow their invisible paths so precisely that from time to time it has been speculated that they certainly possess a special sense unknown to man. At one time they were thought to have kinaesthetic sense, that is, the sensation of position and movement of parts of the body by which they could form patterns of their route through pressure on the inner ear. Another idea was that birds navigate through responses to the earth's magnetic field, perhaps even to its rotational effects. But none of these ideas stood the test of experiment. More convincing is the evidence that a bird's eyes and vision play the primary role in its sense of direction and position. And if the bird locates itself by means of visual landmarks like river valleys or mountains, it is only a step further to the idea advanced by Gustav Kramer and others that a bird might be able to use the sun as a compass and even have a time sense, that is, a 'biological clock', which enables it to adjust its course to compensate for the sun's movement across the sky.

There are also other types of biological time responses which enable an organism to be 'aware' of the time at most periods of the daily cycle. This 'biological clock' guides honey bees to go out to pick up nectar from the flowers at the right time of the day at intervals of twenty-four hours. The honey bees can also 'learn' to visit several different sources of nectar at

different times of the day. Guided by their 'biological clock' several animals, bees and birds can even have time memory and maintain a fixed direction with the help of the sun's azimuth, and even taking into consideration sun's movement through the sky. In these types of biological time responses the animals or the insects appear to be aware of the passage of time, just like our watches tell us the time.

Honey bees have been known to possess 'time memory'. Auguste Forel, a Swiss naturalist, made an intersting observation in 1906. He loved to have his breakfast on the terrace of his home. He noted that every morning the honey bees came to his table to feed on the jam and jellies. Their time of arrival was so precise that Forel kept a watch on them and began to time them with his watch. The bees arrived at about the same time every morning, even if there was no jam or jellies on the table. One day when Forel ate his breakfast inside the house and not on the terrace, the bees came on the terrace at their usual time. He had first thought that probably their sense of smell had helped them to make their scheduled journey at the breakfast time. But now Forel concluded that bees had a 'memory for time' guided by the 'biological clock' and thus were able to observe the time schedule.

A few years later, a German scientist, Von Buttel Reepen, also began to study the behaviour pattern of the bees. He liked to take a walk through buckwheat fields. He observed that the bees stayed in the field until about the middle of the morning and left when the buckwheat flowers stopped their flow of nectar. Von Buttel Reepen found the flowers as fragrant in the afternoon as they were in the morning. But the bees did not come back in the afternoon which showed that the fragrance did not affect the behaviour of the bees.

Von Buttel Reepen concluded that the bees had an actual time sense

Girraj Singh Sirohi

and were guided by an internal clock. He gave a new word Zeitgedach tnis (time sense) to express his idea which is now commonly used both in German and English languages.

Probably, the most outstanding work on 'biological clocks' has been done by Erwin Bunning, who is the acknowledged father of the 'clock' idea. After years of painstaking research in 1936, Bunning put forward his conclusions:

—that plants have an in-built and nearly automatic rhythm which repeats itself at about twenty four hours interval.

—and the organisms use these rhythms to measure time. At that time these ideas were just too fantastic and caused great stir among the scientists. As it so often happens in the early stages of a new scientific idea, enough experimental work did not exist to support the 'clock' idea at that time. Over the years scientists have done a lot of experimental work and the concept of the 'biological clock' has been accepted widely.

The one way to know more about the 'biological clock' would be to watch the behaviour of some plants and animals, whose behaviour is well known to man, in a distant solar orbit where these could be kept away from the effect of light, temperature, rotation of the earth or any other external influences which might be responsible for the rhythmic behaviour patterns.

In 1960, Girraj Singh Sirohi, an Indian scientist was engaged in biological research at the University of California in the U.S.A. He was trying to disprove the theory that the 'biological rhythm' in plants and animals, which causes them to bud and bloom, sleep and awaken, at regular intervals was governed by the rotation of the earth. His experiments on the 'biological clock' could only be carried out at the Poles, where the rotation of the earth is least felt. Sirohi, together with Prof. Hamner (U.S.A.) and T. Hoshizaki (U.S.A.) went over to the Antarctica with some plants and animals for carrying out scientific experiments.

Antarctica is the coldest of the seven continents. Even on the sea-shore in midsummer, the temperature seldom rises above zero degree centigrade. Further inland, the plateau where the South Pole is located is at a very high altitude. So high that in the rarefied atmosphere over the South Pole, existence becomes difficult. This is the only continent on which no human being has lived until recently.

About 180 years ago, Captain Cook crossed the stormy Antarctic Ocean and sailed round the continent of Antarctica. This was the first Antarctic voyage in history. In 1841, Commander James Ross boldly took two ships through the pack ice and sailed two hundred miles further south. Commander Ross discovered the Ross Sea, the mainland of South Victoria Island, McMurdo Sound, the Great Ice Barrier and Ross Island. Ross himself could not explore all the lands he saw. In 1911, Captain Scott surveyed the region, lived there and calculated the extent of the Great Ice Barrier. He journeyed deep into the interior off the continent and reached the South Pole in January 1912, but perished on his way back to the coast. Other daredevils like the Norwegian Amundsen, faced many hazards to reach the South Pole. They paved the way for future scientists.

Sirohi carried out experiments at the South Pole and watched a

number of rhythmic behaviour patterns. He placed hamsters, bean plants, fruit flies and fungi on a specially designed turn-table. This turn-table rotated either from right to left or from left to right to counter the minimal rotation of the earth at the pole. The organisms were kept in constant darkness and at constant temperature in some of the experiments.

The plants and animals followed their usual routine even at the Pole and there was no influence of earth's rotation. The hamsters went off to sleep about six in the morning and woke up at about six in the evening. They kept their twelve hourly schedule. After sleep, they started running about in search of food even though there was no food to be found. The bean plants opened their leaves in the morning and closed them in the evening. The fruit flies hatched every twenty-four hours in the early hours of the day. The fungi which could be observed on petri dishes showed light and dark rings of growth every twenty-four hours. Sirohi had become the first scientist to prove that the computer-like sense of time in insects and plants is independent of earth's rotation. He had shown that the 'clock' was biological.

The idea of 'biological clock' has enabled scientists to understand better many natural phenomena in the lives of plants, animals and even human beings. As we will see in the next chapter, this knowledge is now finding varied applications in scientific laboratories around the world.

4

BIOLOGICAL CLOCK :

In The Service of Mankind

For years, the timing mechanism in plants and animals has been observed, but only about four decades ago the concept of the 'biological clock' came to be widely accepted. As we have noted earlier, the idea of 'biological clock' has contributed greatly to the understanding of the life sciences and has begun to be used for our benefit.

In medical science, the basic understanding of the 'biological clock' has enabled scientists to find a variety of applications. For example, an elderly lady in New York City was unable to sleep until about three in the morning. After going to sleep at such a late hour, she did not get enough rest before going to her office. As a student also she had always found it difficult to keep awake in the classroom without taking a lot of coffee. No amount of drugs or other treatment could help her. Eventually, she was cured, not by a drug but by resetting her 'biological clock'. It was discovered that her internal clock was totally out of harmony with most of us and she was unable to keep the same schedule as we do. Recognising her real trouble, the doctor suggested to her that she may begin to go to sleep at

3 a.m. on the first day, then shift the bedtime to 6 a.m. on the second day. She was advised to shift her bedtime by three hours every day in the same manner. This experiment worked on the woman magically. In about a week she had worked around the clock to a reasonable bedtime.

For the first time in years she did not have to depend on sleeping pills and was able to get a good night's rest. By shifting the bedtime, the doctors helped her to readjust her 'biological clock'.

The 'biological clock' in humans is most clearly evident in the sleep and wake up cycle. The ability to wake up at the set time every morning without the aid of an alarm clock is an excellent example of the innate time sense.

For most people, biological alertness peaks in the morning and early evening. It dips in the afternoon and is at its lowest ebb between midnight and dawn. The body clocks exert enormous control, dictating a person's desire to sleep or remain wakeful. Man's 'biological clock' which synchronises daily to sleep-wake cycle, is influenced by environment, light and meal timings. The high speed travel by aeroplane brings about sudden change of time and upsets the body rhythm, resulting in a 'jetlag' and causes physical and mental stress. People working in night shift experience similar disturbance.

By experimenting with the effects of light, air, temperature and environment on plants and animals, scientists are learning how to control the 'biological clock'. If they somehow manage to speed up or slow down the 'biological clock', they would be able to develop crops that ripened quicker, fish that multiplied faster. The possibilities are endless.

Erwin Bunning has noted that in the human body there is a possible relationship between the rhythms of stomach and liver. If these rhythms

are disturbed, this can cause gastric ulcers. Disturbance in the relationship of other bodily rhythms can result in different diseases. Experimenting with cockroaches, Harker had found that by implanting the ganglion (a part of the body of cockroach) into an insect which had a clock shifted by twelve hours (as part of the experiment) caused the formation of tumours. Physicians have also noted disturbances which may occur when people work day and night shifts. These observations have led to better understanding of the cause of different ailments.

In agriculture, the concept of the 'biological clock' has been very beneficial to mankind. It is well known that flowering in crop plants depends on the day length and temperature. In crop plants like wheat and rice better understanding of the response of plants to day - length and temperature has been used for producing

better varieties of wheat and other food crops. New varieties have been produced which suit different climatic conditions. Using the knowledge about available day length and temperature in different seasons, food crops have been developed which can be grown in those seasons. It has become possible to affect a change in a variety of cotton which was suitable for growing in southern India. This variety can now be grown in Delhi. Many varieties of crop plant seeds have been developed which can be grown in different climatic regions of India. Also, in order to take best advantage of soil and climate in a particular region, special seed varieties suitable for that region have also been developed.

The most important of all the 'biological clocks' in the human body is a tiny cluster of neurons or nerve cells, placed in the base of the man's brain just behind the eyes. It is given the name Suprachiasmatic Nuclei (SCN). Biologists are now sure that this tiny pineal gland in the brain is responsible for different body rhythms. This gland varieties have been

produced which suit different climatic conditions. Using the knowledge about available day length and temperature in different seasons, food crops have been developed which can be grown in those seasons produces a hormone called Melatonin The secretion of Melatonin is high during the night and very low during the day. Melatonin is responsible for circadian rhythms and seasonal physiological changes and behaviour patterns in man. It works like an alarm clock, telling the body gently that it is time to sleep and it is time to wake up. Unlike the animals, the man can modulate its effects and is capable of ignoring it.

Bright light has been found a major culprit to disturb the biological clock and the cells of the eyelids particularly react violently. It is known that photoreceptors in the eyes are linked to a person's body clock, the circadian rhythm of a human being. Recently however, scientists in the U.S.A. had discovered that the back of the knee can be used to help control the 'biological clock' of human beings. By applying bright light to the back of the knees, it is possible to adjust the need to sleep and wake either forward or backward. This opens up new possibilities to give relief to shift workers, persons suffering from jetlag and to those having sleep disturbance problems.

Studies at the University of Minnesota, U.S.A. have shown that biological rhythms can influence susceptibility to disease, response to therapy and performance on a wide variety of mental and physical tasks. Scientists now believe that working with the rhythm of the human body, it is possible to determine the timing of a meal which could tip the scale between health and disease. Researchers in France are finding out the best time to administer medicines for improved effectiveness. With better understanding about the working of the 'biological clock' in the years to come, many more interesting possibilities will be explored to use the knowledge in the service of mankind.

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All living beings have their own 'built in' biological clocks which work constantly with precision even when they are kept in constant darkness and at constant temperature. A natural time sense guides not only everyday life of the plants, birds and animals but also their seasonal behaviour. This innovative scientific idea has contributed enormously to the understanding of the life sciences in our country.

The book explores the scientific concept behind this natural mechanism and present some fascinating examples in nature. It also gives a simple account of the scientific pursuits in this field and how this knowledge can be used in the service of mankind.